REMARKS

By the present amendment, claims 3-6 and 16-17 are pending in the application. Claims 16 and 17 are independent claims.

Claim Objections

Claim 16 was objected to because the symbol "-" between semi and conductor needs to be deleted. By the present amendment, claim 16 has been amended to delete the symbol "-" between semi and conductor.

In view of the present amendment, it is respectfully requested that the objection to the claims be withdrawn.

§103

Claims 3-6, 16 and 17 were rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 4,940,181 to Juskey, Jr., U.S. Patent No. 5,470,787 to Greer; U.S. Patent No. 6,254,923 to Boyd et al. in view of the Periodic Table of the Elements.

These rejections are respectfully traversed.

The Present Invention

The invention of the present application relates to the art of semiconductor devices to be flip chip bonded to a substrate.

A general process for flip chip bonding a semiconductor device to a substrate is illustrated in Figs. 1A to 1H, attached hereto.

Attached Fig. 1A shows, at the left side, a silicon wafer in which a number of semiconductor devices are fabricated together, and, at the right side, a section of an electrode pad of aluminum of a fabricated semiconductor device formed on the wafer with passivation.

On the electrodes of the devices, UBMs (Under Bump Metals, which are referred to as laminated layers in the specification of the present application) of, for example, Ni and Au are formed (Fig. 1B). Solder balls are then formed on the UBMs.

Traditionally, the formation of bumps is carried out by a printing process, in which solder paste is applied on to each of the UBMs, and is then fused for reflowing at an elevated temperature to be bonded to the electrode through the UBM, during which the solder paste is formed into a dome-like shape by the action of surface tension. Alternatively, solder material is plated on the UBMs using a photo resist mask, the solder is then raised to an elevated temperature to be fused and formed into a dome-like shape. See Figs. 1C and 1D, attached hereto.

The wafer is then diced to provide individual chips (semiconductor devices), as shown in attached Fig. 1E. The chip is connected to a mounting substrate by bonding (flip chip bonding) the bumps of the chip to the electrodes of the substrate. For the bonding, flux is applied to the electrodes of the substrate so that the bumps are connected to the electrodes of the substrate through the intervening flux. The assembly of the chip and the substrate is then heated to an elevated temperature to fuse the solder bumps

and accomplish the bonding of the chip to the substrate. See Fig. 1F, attached hereto.

If the heights of the bumps vary widely at this stage, the connection between the bumps and the electrodes of the substrate is frequently bad. Therefore, it is important that the bumps formed at the stage depicted in Fig. 1D have uniform heights or volumes. In other words, the variation in the heights or volumes of the bumps is one of main causes of fault of an expensive semiconductor device (see the right side of attached Figure 1H).

Appendix I, attached hereto, illustrates the three processes for the formation of bumps.

The invention of the present application provides a semiconductor device having solder balls of its electrodes, as shown in the right column of attached Fig. 1C, which are made into bumps having a uniformity of heights after reflowing (Fig. 1D). This is made feasible by the use of the solder balls, the balls being uniform in their heights (or diameters), which is a feature of the present invention. See attached Appendix II.

As shown in the right column of attached Fig. 1C, in the invention of the present application, a certain amount of flux is applied to each of the UBMs provided on the electrodes of a semiconductor device, and a solder ball is fixed (adhesive bonded) to the electrode using adhesion of the flux. Accordingly, the semiconductor device of the present invention comprises the solder balls provided on its electrode, with the balls being fixed to the electrode by

the adhesion of the flux, and not yet having been reflowed. The solder balls are reflowed at an elevated temperature and are formed into bumps, which are uniform in height because of the use of the solder balls which are uniform in diameter. As such, the semiconductor device of the present invention does not have bumps but does have solder balls.

The semiconductor device of the present application is finally mounted on a substrate. In the case where balls are mounted on a chip previously diced from a wafer, the formation of the bumps and the mounting of the chip to a substrate can be performed at one reflowing, as described below.

The semiconductor device of the present application can be isolated, as a chip, from others by dicing a wafer, and solder balls can be then fixed to the UBMs of the electrodes of the device (chip). Using this device (chip) of the present application, the electrical connection between the solder balls (bumps) and the electrodes of the device and the electrical connection between the balls and the electrodes of a substrate can be simultaneously achieved. Thus, the device of the present invention allows flip chip bonding of the device to a substrate by one heating (reflowing) process. Furthermore, the device of the present invention provides the bumps certainly connecting the electrodes of the device to the electrodes of the substrate. In addition, with the invention of the present application, solder balls can be selectively provided only on the devices (chips) of good quality. These benefits cannot be obtained

using conventional techniques for the formation of bumps (evaporation, plating, and screen printing). (See attached Appendix II). This is because the conventional methods need to subject a wafer to processes using a mask and a resist material, and the formation of bumps for a diced individual chip is very inefficient.

For the purpose of reference, the attached article, Micro-Ball Wafer Bumping for Flip Chip Interconnection, demonstrates the superiority of the unreflowed solder ball to bumps formed by a conventional process, such as evaporation, plating, or printing. In particular, Fig. 12b compares height variation of bumps formed from solder balls with bumps formed from printed solder paste. (It should be noted that although Fig. 12b contains two graphs, the upper graph was designated as Fig. 12a when the authors, including the inventors of the application, sent the draft to IEEE, as can be seen in attached Appendix III).

Patentability

The invention of the present application is set forth in independent claims 16 and 17, which the Office Action has rejected based on Juskey, Jr. and Greer.

Juskey, Jr., cited by the Office Action, relates to the bonding of the chip (or wafer) to a substrate, which corresponds to the step illustrated in attached Fig. 1F. The chip is provided with bumps which have already been connected to the electrodes of the chip through a reflowing process. In contrast, the device (chip) of the present invention is

provided with solder balls fixed (adhesive bonded) to its electrodes through flux, and does not have bumps resulting from the reflowing of the balls. In other words, the bumps of the chip of Juskey are electrically connected to the electrodes of the chip, whereas the balls of the device (chip) of the present invention are not electrically connected to its electrodes since the balls have not been subjected to a reflowing process and there is flux between the balls and the electrodes. The balls are fused at the step of reflowing before or when mounting the device to a substrate, to be thereby formed into bumps electrically connecting the device to the substrate.

Flux is also used in Juskey. However, the flux is for the bonding of the chip to the substrate using the bumps provided on the chip, and is applied to the electrodes of the substrate. In Juskey, the bumps are formed by a conventional bump formation process, such as plating, screen printing, or evaporation, as discussed above.

As such, Juskey does not disclose or suggest the semiconductor device of the present invention.

Greer discloses a semiconductor device having as-deposited solder bumps, and does not describe a device having solder balls fixed to its electrodes through flux.

Therefore, the present invention, as defined in independent claims 16 and 17, is not disclosed or suggested by the combination of Juskey, Jr. and Greer. Accordingly, claims 16 and 17 are patentable.

Boyd and the Periodic Table of the Elements were only cited against dependent claims 3-6. If independent claims 16 and 17 are patentable, dependent claims 3-6, dependent thereon, are patentable.

It is therefore submitted that independent claims 16 and 17, and claims 3-6 dependent thereon, are patentable.

CONCLUSION

It is submitted that in view of the present amendment and foregoing remarks, the application is now in condition for allowance. It is therefore respectfully requested that the present amendment be entered and the application, as amended, be allowed and passed to issue.

Respectfully submitted,

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